SUBSTITUTE MATERIALS IN TIME OF WAR

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IN war time the demand for increased production and the restriction of supplies of certain vital materials made it necessary to consider the introduction of substitute materials. The following is a brief account of some of the investigations on substitute materials made at the Laboratory for Scientific Production Research in Charlottenburg during the Great War, 1915 to 1917.

The most important applications of substitute materials are those concerned with production processes such as :—

(1) Machine tools and their drives, for which we require cast iron, nickel steel, nickel chrome steel, belts for drives and non-ferrous alloys, which include copper, tin, zinc, white metals and aluminium.

(2) Lubricants, for which we require either natural or artificial materials for the production of oil.

(3) Cutting tools, which involve the use of tungsten, cobalt, vanadium and molybdenum.

(4) Coolants for which we require mineral oil, saponifiable oil and soda.

1. Machine Tools.

Machine tools are the basis of any manufacturing process. The investigations carried out by the Research Department were chiefly concerned with substitutes for bearings made of scarce non-ferrous alloys, substitution for heavy machine tool beds, stands, uprights etc., so that a saving in cast iron could be effected, and substitution of fabricated materials for leather belts.

Bearings.

To permit the safe and efficient operation of machine tools, the bearings must be made of reliable materials which will withstand the large forces caused by roughing cuts and the high speeds necessary for finishing cuts. Sometimes machines are called upon to withstand combinations of high speeds and heavy pressures, as for

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example, in the roughing of steel shells of small diameters. Although these machines are continuously subjected to severe conditions night and day, the bearings are expected to function without seizure or other forms of failure. The components produced on these machines must conform to prescribed limits of accuracy, for interchangeability is essential in mass production. Faulty spindles frequently have a direct influence on the accuracy of the work piece, so that reliable bearings are indispensable.

The bearings of main spindles are made either as plain journals using bronze or white metal, or as chrome steel ball or roller bearings.

In some cases, where it is necessary to raise the speed of production and at the same time reduce the consumption of copper, it is possible to replace plain bearings by *roller bearings*. This can

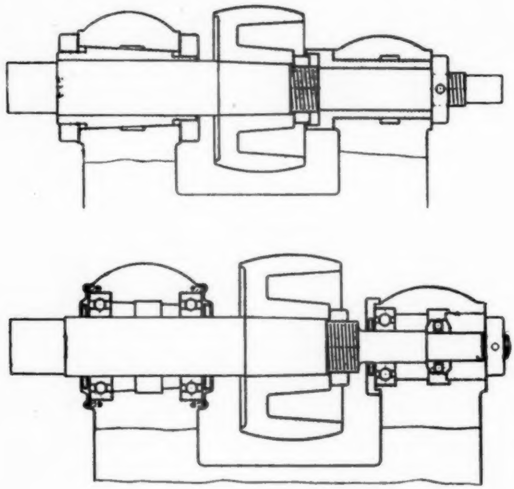


Fig. 1.

only be done where space permits the introduction of at least two radial ball or roller bearings at the front end of the spindle and one radial and one thrust bearing at the rear end, Fig. 1. This modification always entails an increase in initial expenditure, but does not cause any considerable delay in the production of new machine tools. At the time that these experiments were made, ball bearings were not extensively used in Continental machine tools, because the accuracy of commercial ball bearings was below that required for first class machine tools. The allowance for true running and for

axial slip of the main spindle is about 0.0005 in. and only special bearings, the manufacture and selection of which entails a considerable increase of price were capable of fulfilling these requirements. Another disadvantage at that time was that both races and balls were manufactured of chrome steel having a specification such as 1% C, 1.5% Cr., 0.4 Mn., 0.3 Si., 0.26 Ni., which was difficult to supply owing to the scarcity of chrome and nickel.

As the plain bearings were simpler and could be run up to 500 r.p.m. for small and medium machines without danger, if the lubrication was good, the introduction of ball bearings as substitutes was almost dropped. The task of replacing copper alloys like brass and bronze for bearings and gears, wherever it was possible, in lathes, milling, drilling and grinding machines then became very urgent. The responsibility of introducing substitute materials, the reliability of which was not proved by actual years of service, was very great. It was resolved to make, without delay, running tests under actual working conditions without wasting too much material. The machines were carefully checked while working under the extreme loads, to which they were likely to be subjected while engaged on actual production.

The Production Research Department made the programme for these tests and completed the preliminary investigations in eight weeks. Standard headstocks were taken from machines engaged in actual production and changed for the trials. Leading machine tool makers were ordered to send headstocks of complete machines without changing the designs, but simply replacing bearings, bushings, gears and nuts, generally made of phosphor-bronze or brass, by substitute parts made of cast iron or war-bronze, to the designs prescribed by the Research Department. Wherever this simple substitution proved successful, no further change in the design of the machine was undertaken.

Six machines were tested :

(1) A single drive headstock of a lathe of 10 h.p., 250 to 1000 r.p.m., (shell turning).

(2) A horizontal milling machine, knee type, belt driven, 5 h.p., 20 to 380 r.p.m., (gun parts).

(3) The headstock of a capstan lathe, 2 to 3 h.p., 300 to 1200 r.p.m., (fuses).

(4) The headstock of a small lathe with back gear, about 2 h.p., 300 to 1500 r.p.m. (fuses).

(5) A small lathe of 1 h.p., without back gears, up to 2000 r.p.m. (fuses).

(6) A headstock for an internal grinding attachment for 0.5 h.p. and 3000 to 8000 r.p.m. (races).

The duration of the tests was ten hours without any interruption.

This corresponded to the actual running time which occurred during the eleven hour shifts, (two shifts per day), normally worked in armament factories at that time. The eleven hour shift could not be exceeded, for one hour's rest in every twelve was found to be essential for the safe working of these machines.

The following combinations of materials for main spindles and bearings, respectively, were investigated :—

1. Hardened main spindle on :
   (*a*) cast iron bushing,
   (*b*) zinc-bronze (war-bronze),
   (*c*) hardened steel.
2. Unhardened work spindles of hard steel on :
   (*a*) cast iron,
   (*b*) zinc bronze,
   (*c*) hardened steel.

Permissible rubbing speeds between spindle and bearing had to be adapted to suit spindle speeds between 20 r.p.m. and 8000 r.p.m. Today, using well lubricated high speed bearings, the following speeds and pressures are permissible :

Velocity in feet per second of rubbing surfaces	20	30	40	60	75 ft./sec.
Permissible pressure in pounds per square inch	165	190	205	225	230 lbs./sq. in.

The chemical composition of :

(1) a good bronze was generally 90 Cu., 10 Sn.,
(2) a good brass 82 Cu., 8 Sn., 7 Zn., 3 Pb.

The war-bronzes were zinc-bronzes of the chemical analysis :

Zinc (Zn.)	94 to 88 %.
Copper (Cu.)	2 to 8 %.
Aluminium (Al.) ... .., ...	3 % (average).
Lead (Pb.)	1.5 to 1 %.
Iron (Fe.)	0.1 to 0.15 %.

Of much greater importance was a cast iron alloy with the analysis : 3.6 C., 2.16 Si., 0.29 Mn., 0.027 S., 0.07 P. The cast iron alloy was well annealed to make it soft, but it had a dense surface and a high tensile strength of 16 tons/sq. in.

As milling machines present the most unfavourable working conditions for substitute bearings, these machines were tested first. Fig. 2 shows the milling machine tested in 1915 and the 20 places (Nos. 1 to 20), where bronze and brass were commonly used. With the exception of the front bearings No. 1, this good cast iron proved an exceedingly satisfactory substitute material.

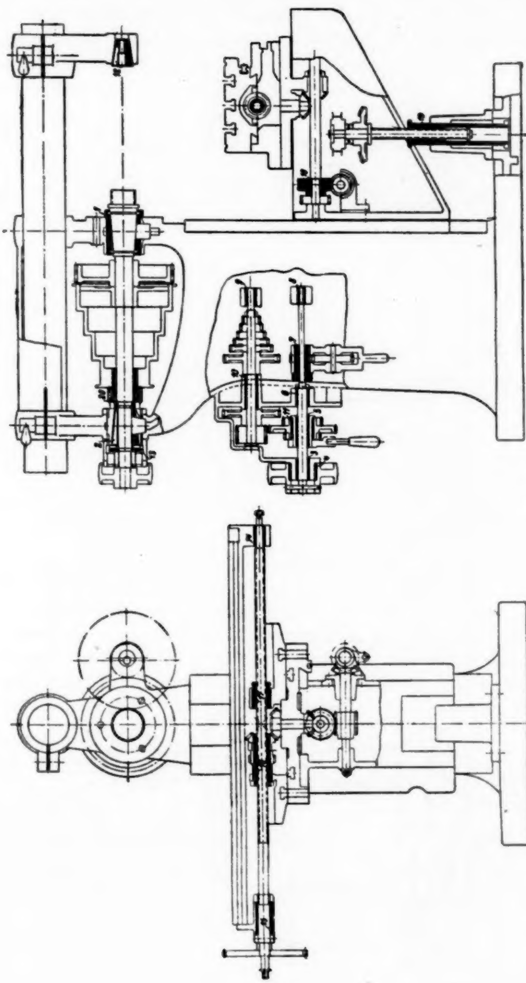


Fig. 2.

Fig. 3 shows how the action of the milling cutter was replaced by a simple arrangement which could be used without changing the milling machine itself, imitating the milling process so far as it affects the load on the bearing.

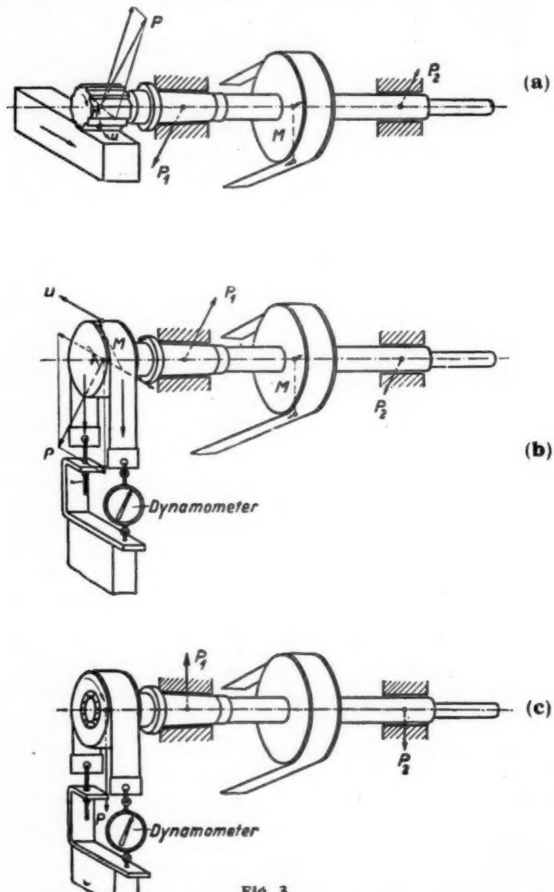


Fig. 3.

Fig. 3a shows the milling cutter exerting a turning moment which affects the spindle only, and single forces which stress the bearings.

In Fig. 3b the cutter is replaced by a plain pulley and a steel belt dynamometer, by which the vertical load can be increased at leisure. The torque and the vertical thrust are separated, because only the vertical thrust and the bending action of the spindle are detrimental to the bearing. We tried to eliminate the torque so that only a thrust acted on the spindle and bearing.

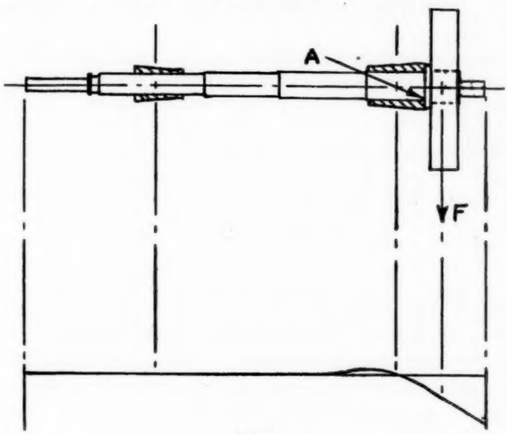


Fig. 4.

In Fig. 3c a stationary pulley mounted on a ball bearing on the spindle nose, replaces the keyed pulley on Fig. 3b, which absorbed power without subjecting the bearings to any additional load. The main spindle is thus free to turn without involving unnecessary power consumption, and the direct load on the bearing can easily be regulated during the test. As the area of the bearing surface is

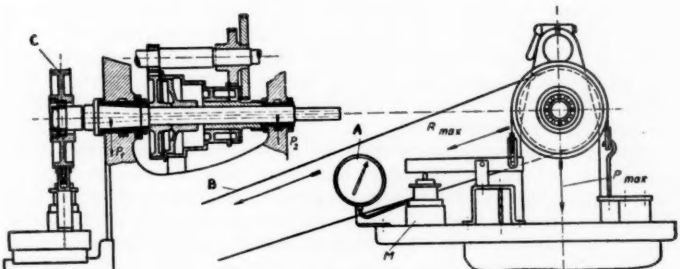


Fig. 5.

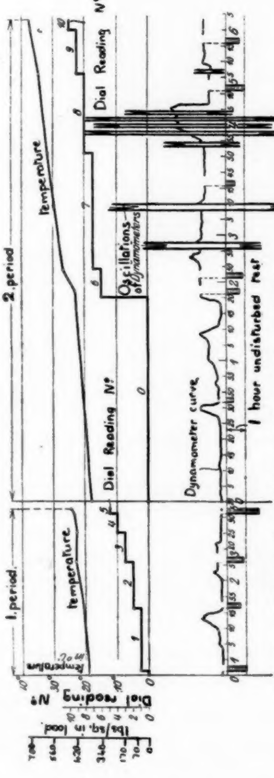
known and the load on the bearing is indicated by the dynamometer, the exact moment of seizure can be anticipated. These increased radial forces tend to bend the spindle beyond the accommodation of the unbent bearing, Fig. 4. If spindle and bearing lose contact in this way, there is a danger that the effective support may be on the *front edge* of the bearing only, giving rise to increased specific pressure on this edge, resulting in seizure and the final destruction of the bearing.

Fig. 5 shows the arrangement to regulate and measure the vertical thrust: A is the indicator of the hydraulic pressure gauge M, C the stationary pulley mounted on the central ball bearing, B the belt which is driving the machine. This belt operates a self-recording dynamometer, which is inserted between the motor and the machine. As the test lasted ten hours, a self-recorder was necessary. The records of this dynamometer showed clearly the internal actions between journal and bearing, Fig. 6. Variations of temperature, the occurrence of metallic friction, and all other relevant factors were recorded either by observation or automatically throughout the test periods. It is essential to know in detail all the effects of introducing these substitute materials into such important working elements of machine tools, for failure would result in the breakdown of the machine and consequent delay in production.

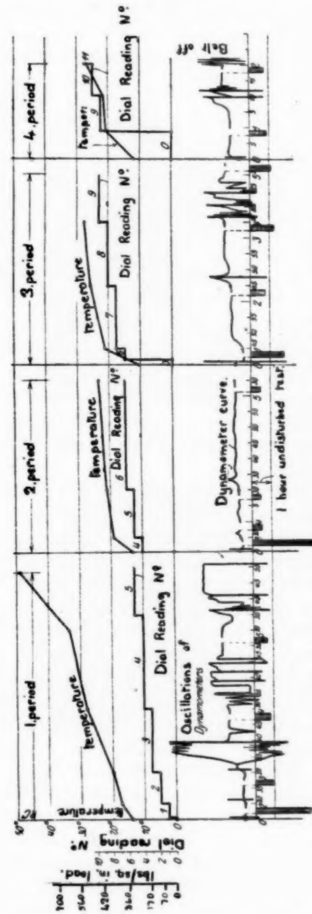
The most sensitive checking instrument, and at the same time the simplest, is the mercury thermometer which measures the temperature of the bearing. The recording dynamometer shows the moment of actual seizing between spindle and bearing, but the thermometer shows very clearly, by a slow continuous increase of temperature long before the seizing occurs, that unfavourable conditions are developing. Load changes are followed very closely by corresponding changes in temperature. If the load remains constant at any given value the reading of the thermometer also remains constant, once the period of running-in under the new load is completed. In the case where the front edge of the bearing is subjected to excessive pressure the temperature gradually increases until seizure occurs. So long as the increase of temperature is slow, it is only necessary to read the thermometer every quarter of an hour, but if a marked increase occurs, it may be assumed that dangerous conditions are developing and the instrument should be watched very closely.

The two diagrams show that for hours the dynamometer stood constant and the amperemeter had very slow variations whereas the temperature of the bearing increased with each change of the load up to the maximum. In the graphs, the vertical blocks on the zero line indicate where the graph is broken up because the reading hardly changed for hours. The old rule that 40°C. (= 100°F.) are the limit of safe running of plain bearings is obviously a good one.

The following table shows the specific pressures exerted during the foregoing tests on the front and rear bearings. The pressure on the front bearing (downward) varied between 28 lbs. per square inch and



Graph of Zinc bushing with good result.



Graph of Bronze bushing with standard War oil.
Fig. 6.

570 lbs. per square inch, while that on the rear bearing (upward) varied between 14 lbs. per square inch and 180 lbs. per square inch.

The bearing surfaces at the front and rear bearings were 12.5 square inches and 8.8 square inches respectively, excluding oil grooves.

Dial reading of steel belt dynamometer No	Actual load on front bearing No 1 Lbs	Bearing pressure on front bearing Lbs. sq. in.	Actual load on rear bearing No. 2 Lbs.	Bearing pressure on rear bearing Lbs. sq. in.
0	360	29	118	13.5
1	870	70	122	14
2	1450	116	240	27.4
3	2050	163	355	40
4	2600	208	495	56
5	3200	255	615	70
6	3800	303	770	87
7	4300	345	910	103
8	4900	392	1050	119
9	5500	440	1200	136
10	6000	480	1330	150
11	6600	530	1460	165
12	7150	570	1600	182
	Pressure on the front edge.		No unilateral increased pressure.	

These tests revealed conclusively that seizure in the front bearing was likely to occur before failure elsewhere. As a result it was decided *not to use substitute materials for the front bearings*, but to retain here good phosphor-bronze bearings. In all other places, where conditions were not so severe, the substitute materials recommended and used in the tests were adopted in the standard machines.

The tests also show, that it is necessary to *harden the bearing section of the main spindle* but that in other cases hardening was not necessary, provided a steel of 170 to 180 Brinell was used in conjunction with cast iron or zinc-bronze bushings.

Further tests showed that *hard cast iron bushes* (2.3 Mn., 1.2 Si.,), were entirely unsatisfactory.

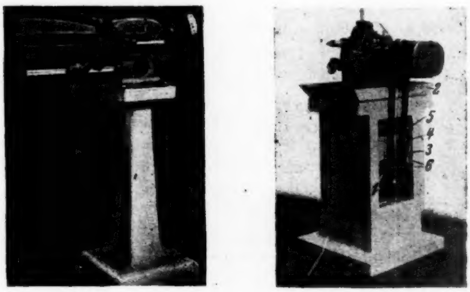
Steel, which is not hardened, runs well on soft cast iron provided correct lubrication is effected. This substitution is particularly suitable in the case of auxiliary shafts.

The use of drop lubricators with feed glasses is satisfactory provided the capacity of the lubricator is sufficiently large. In many cases, where these substitute bushes are introduced, it is desirable to increase the size of the lubricator.

Tests were also conducted with *hardened steel spindles in hardened steel bushings*. particular attention being paid to spindles of small diameter up to about 1¾ in. The results were not encouraging, for seizure occurred at rubbing speeds of 13 to 16 feet per second, when the bearing pressure was 40 lb.s per square inch. Better results may be obtained, if special steel and appropriate hardening (nitriding) processes are used. Care must be taken, that there are no oil grooves parallel to the axis of rotation or in positions subject to direct loading. In addition, the lubricant should, if possible, be

introduced into the bearing at the point of minimum pressure. The edges of all oil grooves should be well rounded.

The small grinding attachment (No. 6 page 261) had a hardened steel spindle, 1 in. diameter, with a taper front bearing of hardened steel and a cylindrical rear bearing, running in adjustable cast iron bushings. The rubbing velocity varied between 7 and 27 feet per second and the bearing pressure varied up to 10 lbs. per square inch. It worked satisfactorily.



(a) Fig. 7. (b)

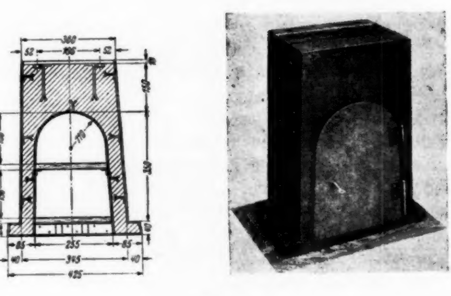


Fig. 8.

Machine bases, beds and stands.

The bases of machine tools must be heavy and rigid to withstand the large cutting and driving forces, which tend to set up undesirable vibrations. Where it is possible to replace these heavy machine parts by *concrete* a considerable saving of cast iron can be effected.

In 1917 and 1918 an attempt was made to replace the cast iron beds of lathes and capstan lathes by solid reinforced concrete beds

having guiding and bearing surfaces of fine hard cement. The result was a complete failure. The ways acted as a grindstone against the carriage and the fine dust which was worn from the cement combined with oil to form an abrasive paste which quickly ruined both beds and carriages.

Although concrete is not satisfactory for bases that include guiding and bearing surfaces, it is useful as a substitute material for heavy machine bases which have no wearing surfaces.

Fig. 7a shows, how concrete may be used for the base of a circular saw and Fig. 7b shows a small gear cutting machine with a concrete box stand. The sharp edges of such stands should not be subjected to rough handling and heavy impacts and, where possible, it is advisable to have well rounded corners. Where this is not practicable a sheet iron case filled with concrete, Fig. 8, constitutes an effective method of protection. The following table shows the savings in cast iron, that can be effected by the introduction of such bases.

Design	Cast iron	Concrete with iron case		Savings in iron
	Lb.	Lb.	Lb.	Lb.
Fig. 7a—Solid stand ...	90	145	6.6	83.6 =93%
Fig. 7b.—Hollow box stand .	460	470	70	390 = 85%
Fig. 8.—Box shape with case	148	235	41	107 = 73%

The damping capacity and natural frequencies of solid concrete stands were compared with those of corresponding hollow cast iron bases. The comparison was quite favourable for the case of the stand shown in Fig. 7a. The natural frequency of the concrete base was 62 oscillations per second, compared with 52 per second for cast iron. The amplitude of oscillation of the concrete was half that of the cast iron and the damping capacity 2.4 times that of the cast iron. For box stands as shown in Figs. 7b and 8, the comparison is even more favourable.

Most engineers disapprove of the introduction of concrete and similar brittle materials into the workshop but, when adequate supplies of iron are not available, these substitute materials can be used to advantage.

Belting.

It seems to be out of date to discuss the necessity of replacing leather belts by a war substitute, as the single drive is progressing and the direct coupling of the electric motor with the machine tool saves belts. But going through the Country and studying existing machine shops, one finds even today, that only a few very well equipped manufacturing shops run on electric drives only. The

great majority have a mixed drive, using the transmission line for the machines of similar kind and size and reserving the individual drive for those, which are most modern and are used for special purposes and work frequently in night shifts.

It was found, that the average practice in British workshops was to have approximately 30 % of machines in a given shop with individual drives, the remaining 70 % of the machines in that shop being driven from the line shaft. In the years 1914 to 1918, the relation was 10 % to 90 %.

Leather suitable for belts can only be obtained from the strongest hide of sound oxen and as the quantity of cattle available for this purpose in an indusrial country is not usually sufficient to cover the need, it is necessary to consider the introduction of substitute belt materials.

During the Great War, therefore, belts were designed of wire, paper, cotton, pulp, in the most varied combinations and some thousands of workmen were producing these belt substitutes.

The Research Department tested substitute belt materials of many kinds and found that the most frequent source of failure was the permanent stretching, which occurred during use. In order to investigate this characteristic, the machine shown in Fig. 9 was designed. Belts were subjected to tests in this machine for periods ranging from 9 to 37 hours, the belt tension being altered by moving the loading dynamo lengthwise and the elongation corresponding to a given tension being measured on the elongation meter. For comparison, 10 hour tests were used in which stretch of belt, number of times the belt was tightened, and numbers of repairs necessary were recorded. The results of such tests for 30 different

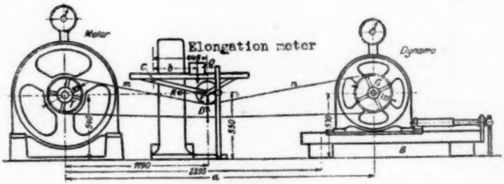


Fig. 9.

belts are illustrated in Fig. 11. Thirty-seven different types of belt fabric are shown in Fig. 10. As a result of this research, it was possible to evolve belt fabrics having an efficiency only 10 % less than that of ordinary leather belts. The only remaining disadvantage of such fabrics is that their life is considerably shorter than that of leather.

It is interesting to note that six months after the war, none of these artificial belt factories existed. The good qualities of leather

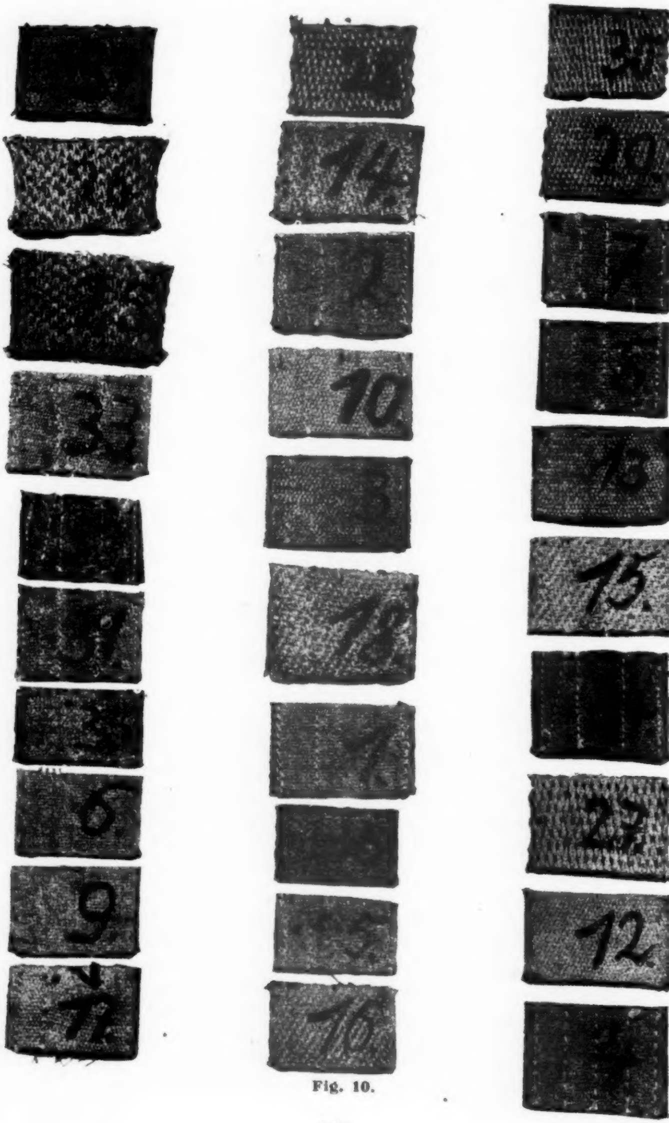
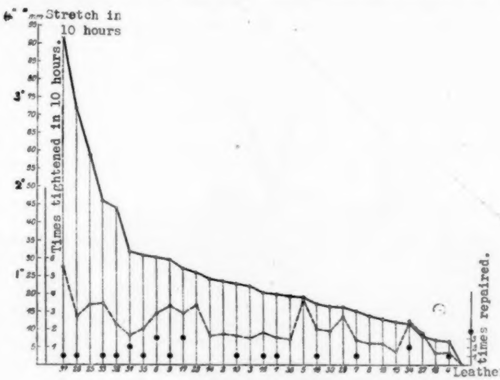


Fig. 10.

belts are so overwhelming that substitute fabrics were quickly abandoned as soon as adequate supplies of leather became available. Nevertheless, these fabrics were of great value during the emergency.

2. Lubricants.

Lubrication is a vital factor in the performance of any bearing. In peace time the necessary oil supplies are readily obtainable from natural sources such as exist in Russia and America, but in time of war countries with inadequate natural sources of oil supply



Extension and failure of belts.

Fig. 11.

must depend to some extent on substitute oils. Only those substitute lubricants which are pure and have a good load carrying capacity can be effectively used in bearings and for gears.

In order to obtain a suitable lubricant, the research department tested five different oils.

(1) R.M.O. (Russian machine oil).
(2) V.I. (Voltol, sliding oil i).
(3) V.II. (Voltol, sliding oil ii).
(4) K.I. (Compound oil i).
(5) K.II. (Compound oil ii).

The research department had to decide (1) whether the R.M.O. which was the machine oil in most general use, was the most suitable lubricant, or whether by the introduction of another oil it was possible to effect a sufficient saving in power consumption to justify the change ; (2) whether the Engler, S.A.E., and Redwood viscosity numbers together with other data obtainable by existing methods

of oil testing, gave reliable indications of the suitability of an oil for use in the workshop ; (3) whether the new methods devised by the research department for oil testing gave reliable results and within what limits these results indicated the suitability of an oil for use in the workshop.

As the different existing oil testing machines did not give reliable indications of the load carrying capacity of lubricants, an ordinary headstock with a single driving pulley was used for testing war oils, Fig. 12. The headstock had eight speeds and the working load could be easily adjusted from zero when running idle to full load and over-load, by a brake drum. Knowing the viscosity of the oil used and the temperatures of the bearings, the efficiency of the machine was changed by *changing the lubricant*. The results observed

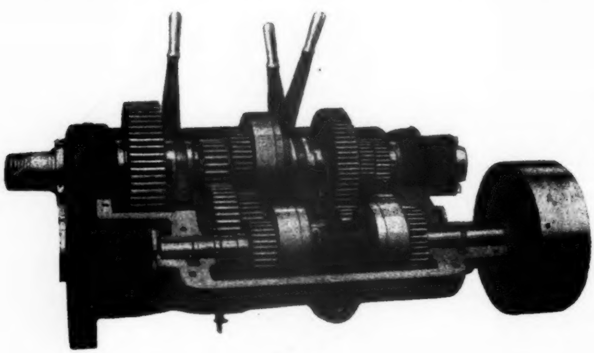


Fig. 12.

included duration of tests, temperature of air, temperature of oil at frequent intervals throughout the test, and power consumptions for the various loads and speeds between 9.25 r.p.m. and 338 r.p.m. The conclusions upon which the suitability of an oil was based were (1) temperature of the oil and the machine ; (2) efficiency of the machine for given loads ; (3) quantity of oil consumed in lbs. per unit of work done (kilowatt hour). The viscosities of the various oils tested were as follows—

Engler Viscosity

Oil symbol	At 50°C.	At 30°C.
R.M.O. ...	6.75	20.1
V.1... ...	7.82	18.4
V.11 ...	6.82	14.9
K.1 ...	7.13	21.4
K.11 ...	3.86	9.69

The tests, which generally lasted five hours, enabled the research department to classify the oils in order of efficiency. V.1 (Voltol, sliding oil 1) gave the highest efficiency, V.11, K.1, K.11, and R.M.O. having lower efficiencies, in that order. It was surprising to note that the best oil effected a saving in consumption of 25 to 30% for idle running, and 10 to 15% for the loaded machine. As a result of these tests it was possible to compound a so-called " unity oil " which was used during the Great War with good results.

It was evident from the foregoing experiements that the load carrying capacity of oil was one of the most decisive factors influencing its utility in the workshop. Without such experiments it is necessary to know the relation between load carrying capacity and viscosity, if the best oil for a given purpose is to be selected.

The power bill for a machine shop may not be the most important item of expenditure, but savings of 10 to 15% for loaded machines and up to 30% for the unavoidable idle running machines are by no means negligible. Such savings have a favourable effect upon the conservation of the coal supply of the country.

3. Cutting Tools.

During the last war the main components of high speed cutting tools were tungsten and cobalt. To avoid the difficulty of forging these alloys the tools were usually made straight and solid and ground from the solid. The following table indicates the usual compositions of the high speed tools used at that time.

	C	Cr.	Tu.	Co.	Va.	P/S
(1) High speed steel for ordinary work .	0.55 to 0.7	3 to 4.5	12 to 14	—	—	0.03
(2) High speed steel of good efficiency ...	0.55 to 0.7	3.5 to 4 5	16 to 18	5	—	0.03

The percentage of tungsten varied between 12 and 18%, that of cobalt between 0 and 5%. Both metals had to be imported and were very scarce and expensive, but both were indispensible for high speed tools, as attempts to replace tungsten by molybdenum failed at that time. In an attempt to overcome the difficulties of restricted supplies, the solid high speed tools were cut to form tips which were brazed to ordinary tool steel shanks. The advantage that accrued from this procedure was only small, for the life of the tungsten available was not increased. Cemented carbides did not exist at that time.

4. Cutting Oils.

Although cutting oils are not so important as lubricating oils, they are nevertheless required in large quantities to facilitate

machining processes. One advantage of the use of cutting oils is that it considerably increases the life of high speed tools. When such oils are introduced to machines where they have not previously been used, changes of design are frequently necessary. These changes involve the inclusion of pumps, pipes, tanks, and trays for the storage, application, and recovery of the oil during use.

Good cutting oils are composed of mixtures of mineral oil with sulphurised fatty oil. A typical analysis is 20% saponifiable oil,

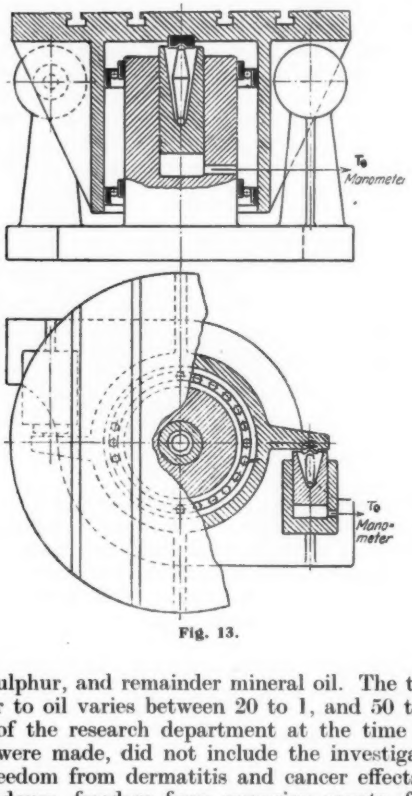


Fig. 13.

1.8% total sulphur, and remainder mineral oil. The thinning relation of water to oil varies between 20 to 1, and 50 to 1.

The task of the research department at the time the tests on cutting oils were made, did not include the investigation of such factors as freedom from dermatitis and cancer effects, absence of unpleasant odours, freedom from corrosive agents, freedom from effects on machine lubricating oil, freedom from gumming and oxydation, freedom from firing at working temperatures, and free-

dom from separation of the constituents at working or store room temperatures. The factors that were investigated appertained to production only and included (*a*) cooling of the tool with consequent increase in life ; (*b*) lubrication of the tool, which reduces wear and saves regrinding and resetting ; (*c*) protection of the machine by the removal of swarf and dust ; (*d*) cooling of the work piece, thus ensuring good finish and accurate dimensions.

For the tests on cutting oils the drilling machine was chosen, for the following reasons. (1) It is comparatively easy in drilling tests to keep all factors constant except the desired variable, in this case the cutting oil ; (2) it is for drilling machines that cutting oil is most frequently used in the workshop ; (3) equipment for efficiency tests on drills was readily available. Fig. 13.

The effectiveness of the cutting oils was judged by the number of holes of equal size which could be drilled under identical circumstances before the drill was dulled. The results were as follows.

(1) Dry tests without lubricants. Cutting edge became so hot that after very few bores, sometimes after one bore, the tool was destroyed. These tests were soon stopped.

(2) Test with pure water. Tool life was very long, the efficiency excellent, but the machine was rusty in a very short time. The use of water as a coolant was rejected.

(3) Soda water tests with neutral 10% soda gave a somewhat smaller efficiency than tests with pure water, but the undesirable rusting effects were eliminated. This coolant was considered quite suitable.

(4) Tests with cutting oils in which the standard oils used in peace time were thinned by water in proportions 10 to 1, 20 to 1, 50 to 1, gave an efficiency less than that when soda water was used. When cutting oil was used the power consumption of the machine was less than when other coolants were employed. This is due to the fact that oil has a greater lubricating capacity than the other coolants. The use of oil has other advantages, for it is much easier to obtain a pure reliable oil than to get pure soda which does not affect the machine or the skin of the operator. In addition cutting oil facilitates the production of well finished surfaces and is particularly suitable for tapping and threading, during which operations it affords better protection for the delicate tool edges than pure water or soda water.

5. Substitutes for Sheet Iron Containers.

Another interesting problem which was investigated by the research department during the last war was that of finding a substitute for sheet iron containers. The object was to use cheap wood and to avoid the use of metal as far as possible. The ordinary iron drum which is used for oil, grease, bitumen, etc., has become

increasingly useful since the introduction of welding, which enables the container to be made leak-proof and air-tight. Two of the chief disadvantages of metal drums are that they are liable to corrosion and are relatively heavy, so that any consignment of goods has a large proportion of dead weight. In war time the chief disadvantage is that iron is urgently needed for other purposes.

Plywood containers are lighter in relation to their capacity than either metal drums or coopered barrels. This is chiefly due to the fact that the arrangement of the fibres of successive layers across one another gives greater stiffness for a given weight. These containers are easily made in cylindrical form, the ends being closed by flanged plywood. Suitable lids are easily made. Fig. 14.

Fig. 14.

The chief difficulty in developing these plywood barrels was the selection of a suitable glue which had to be waterproof, acid-proof, colourless, and odourless so that food stuffs were not contaminated, and resistant to attacks from insects, bacteria, mould, fungus, etc. New glues such as "Kaurit" and "Tego" satisfied these requirements and had the advantage of setting quickly under high temperature and pressure. The setting time for a big container of 50 gallons capacity varied from two minutes to 2½ minutes, with pressures

from 85 lb. per sq. in. to 215 lb. per sq. in. and temperatures from 266°F. to 311°F.

A wide range of woods are suitable for the manufacturing of these barrels, but the best results were obtained with odourless beech, which was quite inexpensive.

A cylindrical plywood container 22 in. diameter, 35 in. long, with walls consisting of three layers, having a total thickness of 0.2 in. could be made in $2\frac{1}{2}$ minutes on a barrel winding machine. At the same time lid and bottom could be made from plywood by hydraulic press. The three layers are fed separately into both the winding machine and the hydraulic press. The glue, which is applied to the wood and allowed to dry before it is used, is remelted as soon as the three layers enter the machine and come into contact with the heated drum which has a temperature of about 300°F. This causes the layers to adhere to one another and continued exposure to heat under great pressure causes the softened glue to harden and set permanently.

Fig. 14 illustrates the waterproof plywood barrels which were used and which varied in capacity from two gallons to 50 gallons. These barrels were made in various grades suitable for the transport of powders, pastes, liquids, etc., under all normal conditions. The technical problems surrounding this form of substitution were solved completely.

COMPULSORY REGISTRATION OF SPECIAL CLASSES OF PROFESSIONAL ENGINEERS

ON Sunday, July 14, 1940, there came into force an Order made by the Minister of Labour and National Service (Mr. Ernest Bevin) entitled "Specified Classes of Persons (Registration) (No. 1) Order 1940" dated July 8, 1940, making registration through the Central Register compulsory for certain categories of professional engineers, including all production engineers above the rank of foreman. The issue of the Order was announced by the B.B.C. and in display advertisements in the press the same day. A copy of the Order is set out later. It does not refer to any penalties for failure to comply with its terms, but the official advertisement mentions that there will be heavy penalty on conviction. *The Times* newspaper of July 15 states that this can be three months' imprisonment and/or a fine of £100.

This measure marks the adoption of a policy that has been advocated by the Institution since the month war was declared. It was evident even then that there would be a shortage of certain classes of engineers and, above all, of production engineers. At the first opportunity, the Council of the Institution placed on record its view of the situation in a series of resolutions which included the following—

"That if those sections of the engineering divisions of the Central Register where a shortage exists are to be made effective, compulsory registration is a necessity and ought to be introduced without delay, since it will be very difficult to carry out if communications are later interrupted and factories damaged or destroyed by enemy air action.

"That the voluntary system in sections where a shortage exists is inadequate and inequitable.

"That the decision to extend the scope of the engineering sections of the Register so as to include experienced engineers outside the ranks of the existing engineering institutions, and in some cases not eligible for admission to them, is sound in principle but cannot be made effective unless compulsory registration is introduced.

"That for shortage sections, immediate action should be taken to establish consultative panels in every engineering centre in the country."

At first, no support at all for these ideas was forthcoming from any quarter, though Mr. J. D. Scaife and other representatives of the Institution pressed them as strongly as possible on official circles from October, 1939 onwards. In March of this year they were put forward lucidly on behalf of the Institution by Lord Sempill in the debate in the House of Lords on the Central Register, fully reported in the March issue of *The Journal*. A powerful reinforcement of the Institution's policy was, however, forthcoming later from the Royal Aeronautical Society, which adopted a similar line and their representations effectively put forward by their Secretary, Captain Prichard, combined with those of this Institution, prevailed, though the Selection Committee of the House of Commons on National Expenditure also at the end threw in its weight on the same side.

The Central Register has not yet functioned to any appreciable extent in assisting industry to recruit personnel, its chief work up to the present having been to cater for the expanding needs in this respect of the various Government departments. With the coming of compulsion, however, which it has been estimated will add 80,000 professional engineers to the 22,000 already enrolled on the Register, the regional machinery will probably be brought into early operation, and it is to be hoped that the scheme can then be worked in such a way as to make an effective contribution to the needs of industry.

It will be noted that the Statutory Order sets out three definitions of the classes of professional engineers to which it applies, one of which is a definition of a production engineer, as follows—

"A production engineer, that is to say a staff engineer who normally holds in any engineering works a position of authority involving responsibility for executive management or control, above the rank of foreman, of any technical function pertaining to production."

In November, 1932 the Council of the Institution adopted a report of its Development Committee on "Production and Production Engineering Terminology" (*The Journal*, Vol. X, No. 9, pp. 221 and 222). That report contained two definitions of a production engineer, one a generic definition covering production engineers of all ranks, and the other applicable only to the senior officer holding the titular position. It is interesting to compare the generic definition approved by the Council in 1932 with the

definition set out in the Statutory Order as quoted above. It was as follows—

> "*Production engineer.* An engineer qualified to hold in an engineering works a position of authority responsible for any technical function pertaining to production."

The Institution was opposed to the inclusion of the words " above the rank of foreman " in the Statutory Order, but was over-ruled on that point on the ground that foremen are already dealt with by the Supplementary Register, and that their inclusion on the Central Register would make the numbers to be dealt with unwieldy. Foremen who are members of the Institution are, of course, entitled to enrol on the Central Register along with other members, and most, if not all of them, have already done so.

The other definition of 1932, applicable to the senior officer holding the titular position, was as follows—

> "*Production engineer.* The executive officer in an engineering works responsible for the technical side of production from the issue of the design from the drawing office to the delivery of the finished product to the despatch department, usually supervising the work of the progress, planning, and jig and tool departments."

When the Central Register was first started the Institution asked for the establishment of a Production Engineering Sub-Committee. This, however, was not set up, in spite of very strong reasons in its favour. Amongst these reasons is the fact that while all other classes of engineers dealt with by the Statutory Order are organised professionally on a vertical basis, mainly according to their own branches of the engineering industry (such as aeronautical, automobile, civil, electrical, gas, locomotive, and mechanical engineering), production engineers are organised on a horizontal basis, since they cover all branches of engineering manufacture. This special position of the production engineer is recognised in the Statutory Order, where he is rightly given a place apart from the others, with a special definition, but it has not so far been recognised in the organisation structure of the Central Register, greatly to the detriment of its effective operation.

The failure to set up a Production Engineering Sub-Committee, like the failure to include production engineers in the list of professional engineers in the Schedule of Reserved Occupations—even now they are not in the Schedule !—dates from the almost forgotten pre-war days of last year, before production engineering came within the ken of official circles and when its place in the scheme of things was not looked on with favour by those who exercise a traditional authority, perhaps sometimes a little out of touch with

present-day realities. The production engineer has travelled some distance since then. The issue of the Statutory Order and its terms bear witness to that.

Members may rest assured that the Institution will watch closely the operation of compulsory registration, and the wider measures to which it may be the prelude. The recently established War Emergency Committee of the Institution is at present meeting every week at London Headquarters, and will keep in close touch with all Local Section Committees throughout the country on this and other questions.

Here are the terms of the Statutory Order, printed and published by H.M. Stationery Office :—

STATUTORY RULES AND ORDERS

1940 No. 1221

EMERGENCY POWDERS (DEFENCE)

Specified Classes of Persons (Registration) (No. 1) Order 1940

THE SPECIFIED CLASSES OF PERSONS (REGISTRATION) (NO. 1) ORDER 1940, DATED JULY 8, 1940, MADE BY THE MINISTER OF LABOUR AND NATIONAL SERVICE UNDER REGULATION 58A OF THE DEFENCE (GENERAL) REGULATIONS 1939.

The Minister of Labour and National Service (hereinafter referred to as "the Minister") by virtue of the powers conferred on him by Regulation 58A of the Defence (General) Regulations, 1939 (a) hereby makes the following Order.

1. This Order may be cited as the Specified Classes of Persons (Registration) (No. 1) Order 1940, and shall come into force on the 14th July, 1940. **Short title and commencement.**

2. Every person to whom this Order applies shall register particulars about himself in the form set out in the First Schedule hereto or in such other form approved by the Minister substantially to the like effect. **Registration of certain workers.**

Applicati[on] for and completi[on] of forms.

3.—(1) Every person to whom this Order applies—

(*a*) shall make application in writing to the Ministry of Labour and National Service, Central Register, Box No. 111, South Western District Office, London, S.W.1, not later than the fifth day after the coming into force of this Order or the fifth day after the date on which he becomes a person to whom the Order applies, for forms for the purpose of the registration aforesaid ; and

(*b*) shall complete the two forms sent to him and deliver them to the above address within three days of their receipt by him. For this purpose forms shall be deemed to have been received by such person on the third day after their despatch to him, and to have been duly delivered by him if they are posted on the last of the three days.

(2) If at any time while a person is registered under the provisions of this Order a change occurs in his name or address or in the place where he is employed or carries on his occupation he shall forthwith notify the change to the Ministry of Labour and National Service at the address set out in sub-paragraph (*a*) of paragraph (1) of this Article.

Applicati[on] of Order.

4.—(1) This Order applies to the classes of persons described in the Second Schedule hereto—

Provided that this Order shall not apply to any person who on any of the above-mentioned dates has already registered with the Central Register, Ministry of Labour and National Service, either directly or through any institution, body or university particulars about himself substantially equivalent to the particulars contained in the form set out in the First Schedule hereto.

(2) This Order applies to any member of the Local Defence Volunteers who is in any of the said classes but, save as aforesaid, this Order shall not apply to any person while he is actually serving with any of the armed forces of the Crown.

Signed by order of the Minister of Labour and National Service this eighth day of July, 1940.

T. W. Phillips,

Secretary of the Ministry of Labour

and National Service.

(*a*) *See* S.R. & O. 1940 Nos. 781 and 907.

FIRST SCHEDULE

Surname (block capitals).	Christian Names.	Mr. Mrs. Miss	Occupation.	For Official Use

Home Address and Telephone No.	Date of Birth. / Married or Single	Branch of work in which expert or specialised.

Nationality.	At Birth.	Now.
Self ...		
Father ...		
Mother ...		

Additionalinformation, e.g. nautical, wireless, knowledge of other countries, hobbies, sports, etc.

Professional, technical, or scientific qualifications, degrees, etc.

Training and **Experience**. Give details of apprenticeship, if any, and of all employment in chronological order.

Salary in latest post.
£ p.a.

Dates Years only.	Name and Address of Employer.	Your own position and duties.

(Front)

State of general health, giving particulars of any disability.

Particulars of Education.

For Official Use.

Languages, if any. Give language in which most proficient first, using the letters A (very good), B (good), C (moderate). State how well you can

Language	Read: Print.	Read: Ordinary Hand-writing.	Speak.	Write.

Particulars of service in any Government Department or with the Services, stating rank held.

State any technical or administrative work either with the Services or in Government Departments for which you regard yourself as having a particular aptitude, and any special qualifications for such work.

Signature ....

Date ....

(Back)

SECOND SCHEDULE.

1. A person who is normally engaged in the engineering profession in a consultant, technical, or supervisory capacity in design, construction, manufacture, operation, or maintenance, and who has had a regular professional training in practice and in theory as an engineer in any of the following branches of engineering, that is to say—

   aeronautical engineering,
   automobile engineering,
   chemical engineering,
   civil, structural, and municipal engineering,
   electrical engineering,
   gas engineering,
   locomotive engineering,
   mechanical engineering.

2. A production engineer, that is to say a staff engineer who normally holds in any engineering works a position of authority involving responsibility for executive management or control, above the rank of foreman, of any technical function pertaining to production.

3. An engineering scientist, that is to say a person who has obtained an Honours degree at any university in the British Empire and who is normally engaged on research work in the engineering sciences at any such university or in research and development work in any industry or as a teacher of engineering science.